Modeling and Characterization of Grain Scale Strain Distribution in Polycrystalline Tantalum

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A common sample geometry used to study shear localization is the tophat, an axi-symmetric sample with an upper hat portion and a lower brim portion. The gage section lies between the hat and brim. The gage section length is on the order of 0.9 mm with deformation imposed through a Split-Hopkinson Pressure Bar system at maximum top-to-bottom velocity in the range of 10-25 m/s. Detailed metallographic analysis has been performed on sections of the samples to quantify the topology and deformation state of the material after large deformation shear, shown in Fig. 1. These experiments, performed with polycrystalline tantalum, have been modeled using a multiscale, polycrystal plasticity approach. A Voronoi tessellation-based microstructural model and a coupled thermo-mechanical elasto-viscoplastic crystal plasticity model were used. The crystal plasticity model allowed for slip to occur on the twelve $\{110\}\langle 111\rangle$ and twelve $\{112\}\langle 111\rangle$ slip systems. Three numerical models were produced using three different realizations of initial crystallographic texture distribution within the same morphological microstructure and the results presented. The results of one of these realization simulations are shown here. The detailed metallographic analysis of the deformed sample shear zone produced an estimate for the strain profile within that region, and these results are compared directly with the three numerical simulation results, given in Fig. 3. The experiments produce lower and upper bound estimates of the deformed strain state in the material due to ambiguity of the initial state for the 2D metallographic technique available. Although the stress response of the models predict a stress response that is greater than that observed experimentally, the local strain response compares very well with the results of the metallographic analysis. Both the experimental and numerical results give estimates of the degree of heterogeneity that exists in the deformation response of metallic polycrystalline aggregates. This heterogeneity is believed to drive the initiation of damage and failure processes.

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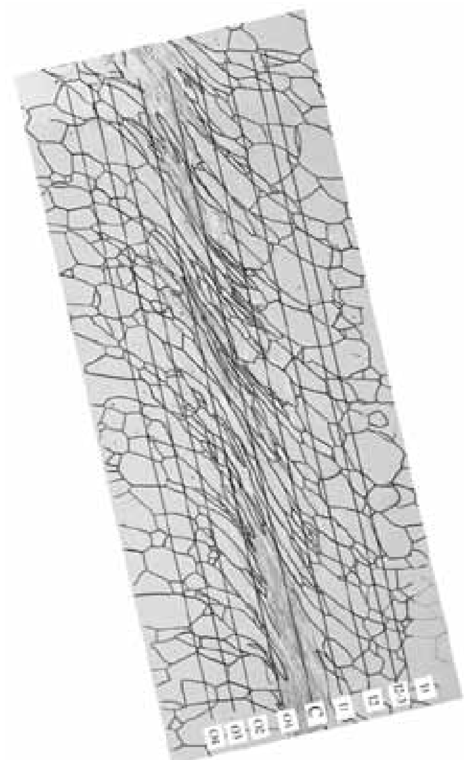
Fig. 1. Digitized shear zone region highlighting the grain boundary structure and used to quantify the deformation profile. Note that measurements were not taken along line I2-3.



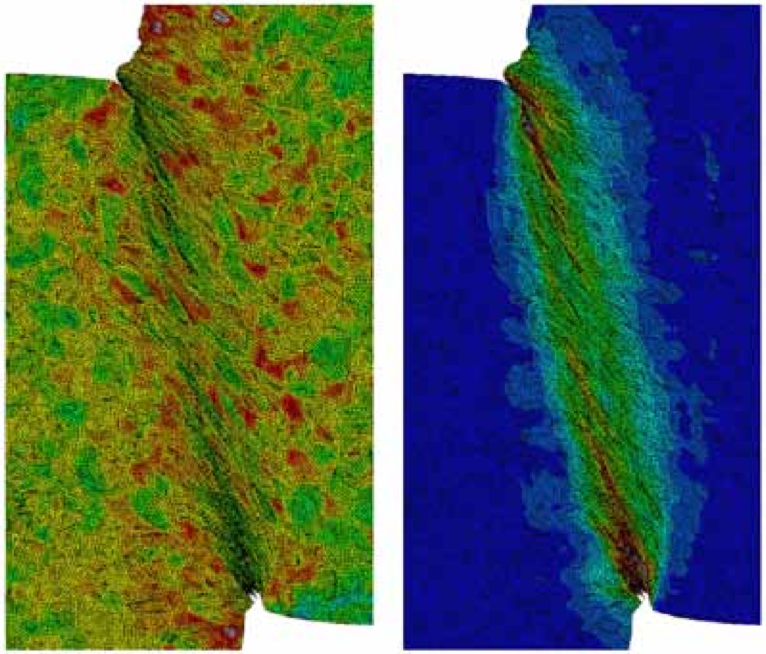


Fig. 2. vonMises stress (left, red=900 MPa) and equivalent plastic strain (right, red=1.5) contours in the deformed mesh of the realization 1 model.

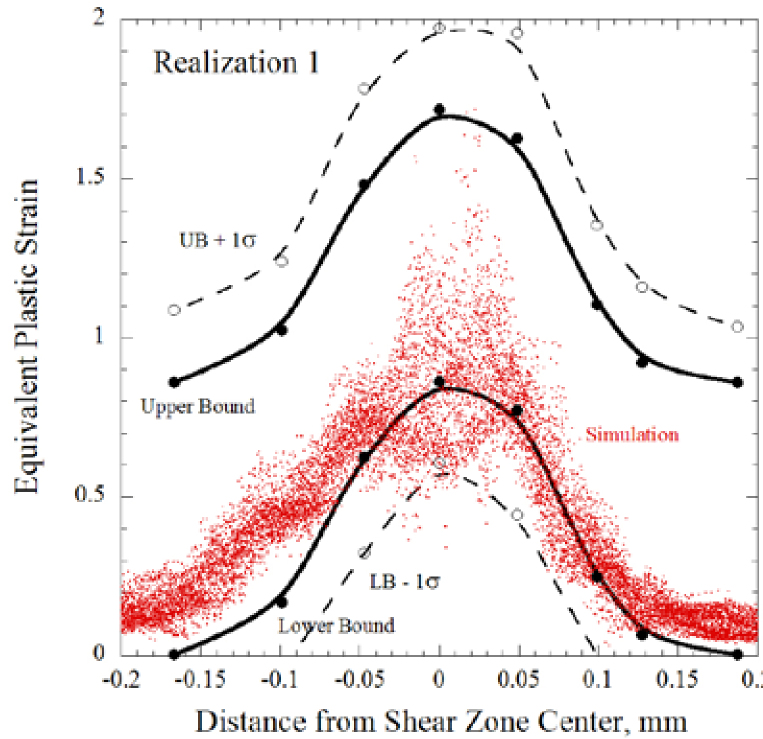


Fig. 3. Comparison of the results of realization 1 simulation to the strain evaluated from grain aspect ratio measurements. Negative position values indicate points nearest to the center of the axi-symmetric sample. The solid curves represent the mean lower and upper bound equivalent plastic strain evaluated from the metallographic images. The dashed curves represent the one standard deviation envelope around the experimental lower and upper bound curves. The red points represent the numerical results from all material points within the extracted shear zone region.

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